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Relationship between Benthonic Foraminiferal Fauna and the Substrate in the Littoral Zone*

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沿岸帯における底生有孔虫群集と底質の関係

エステバン・ボルトフスコイ

アルゼンチンとウルグアイの，南緯約 30–50 度にわたる地域の沿岸帯より得た 110 サンプル中に含まれる底生有孔虫生殻をローズ・ベンガル染色法で識別した。すべてを底質の種類に応じて七つの biotope に分けた上で，1 サンプルあたりの含有生殻数および生殻・死殻比の平均値を比較すると，生殻は生きている石灰藻上の biotope で最も豊富であり，逆に貝殻片を含まぬ砂（いわゆるビーチ・サンド）の biotope に一番乏しいことがわかった。ただし，生殻の死殻に対する比の最高値は，1 サンプルにすぎないが，Puerto Deseado における *Salicornia* の生えているシルトであった。

Introduction

When the Recent foraminiferal faunas are studied, it is very desirable to separate living specimens (encountered with protoplasm) from dead ones (found as empty tests), because the latter do not necessarily live in the place where they are found; they could have been redeposited from other sometimes quite distant areas.

This separation is especially important in studying littoral fauna because shores are often composed of sediment which contains a rich fossil foraminiferal fauna. If these sediments are Mesozoic or older, the danger of interpreting fossil shells as Recent is very small. If, however, the shore-sediments are Neogene or Quaternary, the danger is much greater, because if fossil foraminifera are preserved in good shape, they look exactly like Recent specimens.

Therefore it is very important for everyone who is going to study Recent littoral foraminifera and to collect material in this zone to know in what type of biotope the richest living fauna can be found.

This paper is dedicated to this problem. However, I wish to state that the data obtained should be considered only as preliminary. Much more material (collected in many different areas) should be studied to achieve more representative average data. Nevertheless, I hope that the results of the present study will point out conclusions of interest which will help to the collector to get the richest material possible and to save much of his time and energy.

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Previous Studies

As far as I know, no special study exists with respect to this problem concerning littoral foraminiferal fauna.

Numerous observations on the relationship between the foraminiferal fauna and the substrate are scattered among the papers on Recent foraminifera. Many of these observations are of limited value as their authors worked with unfixed foraminifera. Therefore they could not separate living specimens from the dead ones and thus they based their conclusions on the whole fauna (both living and dead). Some authors used living specimens only. They could consequently determine how many specimens with protoplasm were encountered in different biotopes. Detailed review of all the observations with respect to foraminiferal fauna as related to the character of substrate were published by BOLTOVSKOY (1963, 1965). This author analyzed data from more than 50 studies in which the relationship between the substrate and foraminiferal fauna (living and dead) was discussed. As a result of this analysis BOLTOVSKOY concluded that the most productive substrate is a heterogenous sediment consisting of fine sand mixed with lime and detritus. Nevertheless, this conclusion is of limited interest to a collector interested in the littoral zone because BOLTOVSKOY took into account all the data available without separating the data into those concerning living specimens and those concerning empty shells. Besides, the littoral zone was not the only zone discussed; other quite different depths were also considered. The main task of the present paper, however, is to draw the conclusions with respect to the littoral zone only.

Material and Method of Study

The material studied for the present paper consisted of one hundred and ten samples collected in the intertidal zone along the coast of Argentina and Uruguay (between Latitudes 30° and 52° S). These samples were fixed at the time of collection in a 5-10% solution of neutralized formalin.

Later they were washed in the laboratory through a sieve with average openings of 0.074 mm (U. S. Sieve Series Mesh, no. 200), treated with Rose Bengal, washed again (to eliminate the excess stain) and dried. The treatment with Rose Bengal facilitates very much the separation of specimens with protoplasm from those lacking it, as Rose Bengal stains protoplasm, but not the tests.

The samples were then treated with carbon tetrachloride. This permitted a rough separation by flotation of foraminiferal tests from several heavier inorganic remains.

The floated part was examined under a microscope and 250 specimens taken at random were separated by means of a fine brush and mounted on slides. If a sample contained less than 250 specimens, all the specimens were picked out. The next step was to divide the separated specimens into "living" and "dead" and

to count each group. It was assumed that specimens containing protoplasm were living at the time of collection.

Later all the remaining living individuals were picked out from the sample and the total number of all living specimens was counted.

Discussions and Conclusions

Two pieces of information were obtained from the material studied.

(1) *The average number of living specimens per sample.* These data would be of more value if all the samples collected were of exactly the same volume. Unfortunately this was not the case. However, since a bottom sampler equipped with the same kind of container was always used, I believe that the results obtained could be roughly compared and will give an idea (albeit very generalized) about the relative abundance of living foraminiferal specimens on different biotopes.

The data obtained relative to the number of living specimens are shown in Table 1. The average number of living specimens found in a sample on living calcareous algae could not be calculated because these algae were washed without taking into account their volume or weight.

(2) *The living : dead ratio of specimens.* This ratio proved to be extremely variable for different biotopes. In the great majority of the samples the dead shells very much outnumbered the living ones and in a few samples no living specimens were found at all. On the contrary, there were samples where the living specimens were more numerous than the dead ones. For example, in a sample of calcareous

Table 1. The number of living specimens per sample and the living : dead ratio as related to the character of the substrate

Substrate	Average number of living specimens per sample	Average living : dead ratio
Living calcareous algae (Corallinaceae)	—	44 : 56
Tidal pools with a fond of sand containing molluscan detritus, gravel and sometimes remains of *Corallina*	98	42 : 58
Gravel with sand and silt	29	29 : 71
Fine and medium sand with living pelecypods (*Mytilus*)	80	27 : 63
Silt	110	21 : 79
Sand with a detritus of dead molluscs and calcareous algae	25	9 : 91
Fine, medium and coarse sand without molluscan detritus	17	3 : 97

algae collected in Puerto Deseado Creek, the living: dead ratio of specimens was 91:9.

The variations in this ratio as well as those in number of living specimens per sample apparently depended on the character of the substrate where the fauna was collected. Although the variations in the living: dead ratio in the samples taken from the same type of biotope (but in different points of areas) were also observed, they were not as great as the variations between different biotopes.

In order to insure that the average results obtained were reliable, I took into account only substrate types from which a sufficient number of samples was collected. It was believed that no less than eight samples taken from the same type of biotope should be treated to get more or less reliable data. As the 110 samples studied were not evenly distributed among different kinds of substrate, those biotopes from which less than eight samples were obtained were included neither in the discussion nor in Table 1.

These data indicate that the best substrate to search for living foraminifera in the littoral zone of mid latitudes is one containing living calcareous algae (Corallinaceae). I write "of mid latitudes" because the material for this study was collected between latitudes 30° S and 52° S. It is very probable that another substrate of a very high foraminiferal production is a silt where *Salicornia* is growing. In material collected from this biotope in Puerto Deseado, the living: dead ratio of specimens was still higher (namely 48:52) than in an average sample taken on Corallinaceae. However, as all the samples were collected in the same area (Puerto Deseado) and, besides, the number of samples (only 6) collected from this biotope was less than the number considered necessary to calculate an average (8), I decided not to include these data on Table 1.

Logically, with the change of substrate foraminiferal fauna varies not only quantitatively but qualitatively. However, I prefer for the time being not to draw any definite conclusion with respect to the latter. This problem can be approached more objectively if the material is much richer and collected in the same relatively small area from all kinds of substrate. If the material is collected in different areas, faunal differences conditioned by different substrate will be partially obscured by different latitude.

Summary

The following conclusions with respect to living and dead foraminiferal fauna in the littoral zone of the middle latitudes can be drawn.

(1) The average number of living specimens found per sample and the living to dead ratio are very variable and depend chiefly on the character of the substrate.

(2) The greatest average number of living specimens per sample as well as the largest living: dead ratio were found on the living calcareous algae (Corallinaceae).

(3) Foraminiferologically the poorest biotope is fine, medium and coarse sand which does not contain any molluscan detritus (typical beach sand).

(4) The above pieces of information are useful for people who are going to collect Recent littoral forminifera.

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